

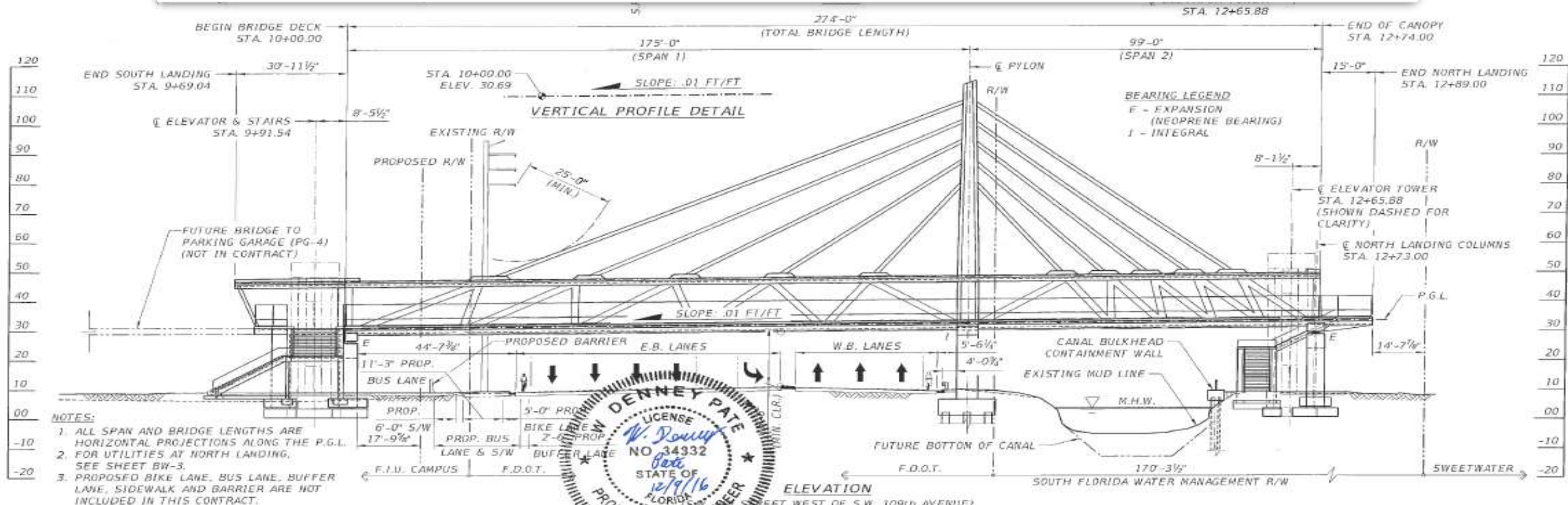
From Design to Disaster: Analysis of the Florida International University Pedestrian Bridge Collapse

Robert Sumwalt
January 30, 2020

FUTURE BRIDGE TO
PARKING GARAGE (PG-4)
(NOT IN CONTRACT)

BURIED ELECTRICAL

ENDING COLUMNS
00
Concrete Sidewalk
21'-7"
E STAIRS



REVISIONS					GENERAL PLAN AND ELEVATION				
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION	SHEET NO.
									8-4

ENGINEER		CHECKED BY		DESIGNED BY		PROJECT NO.		PROJECT NAME	
W. DENNEY PATE		M. J. JADE		E.D.I.		434688-1-58-01		UNIVERSITY CITY PROSPERITY PROJECT	
424 North Calhoun Street Tallahassee, Florida 32301		F.I.U.		FLORIDA INTERNATIONAL UNIVERSITY		PROJECT ID		UNIVERSITY CITY PROSPERITY PROJECT	
FLORIDA CERTIFICATE OF AUTHORIZATION NO. 5618 W. DENNEY PATE, P.E. - P.E. NO. 24332		M. J. JADE		PROJECT NO.		434688-1-58-01		UNIVERSITY CITY PROSPERITY PROJECT	

Printed By: dcmw
10/31/2016 4:28:34 PM G:\434688\15801\Project\DWG\Plate\Rev01.dwg



Our mission:
Prevent Accidents
Reduce Injuries
Save Lives







Michael Graham



Bruce Landsberg



Robert Sumwalt



Jennifer Homendy



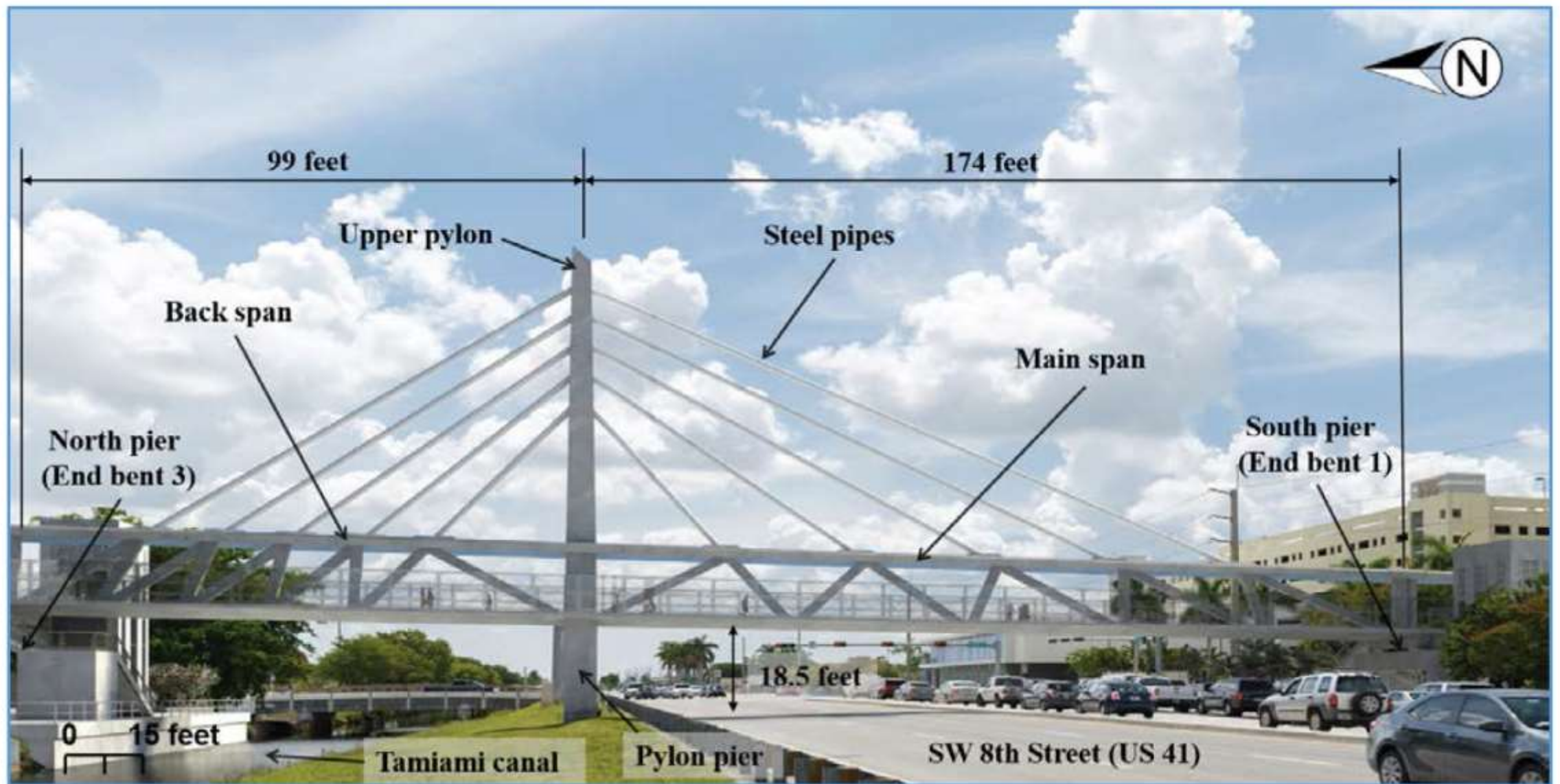
Thomas Chapman



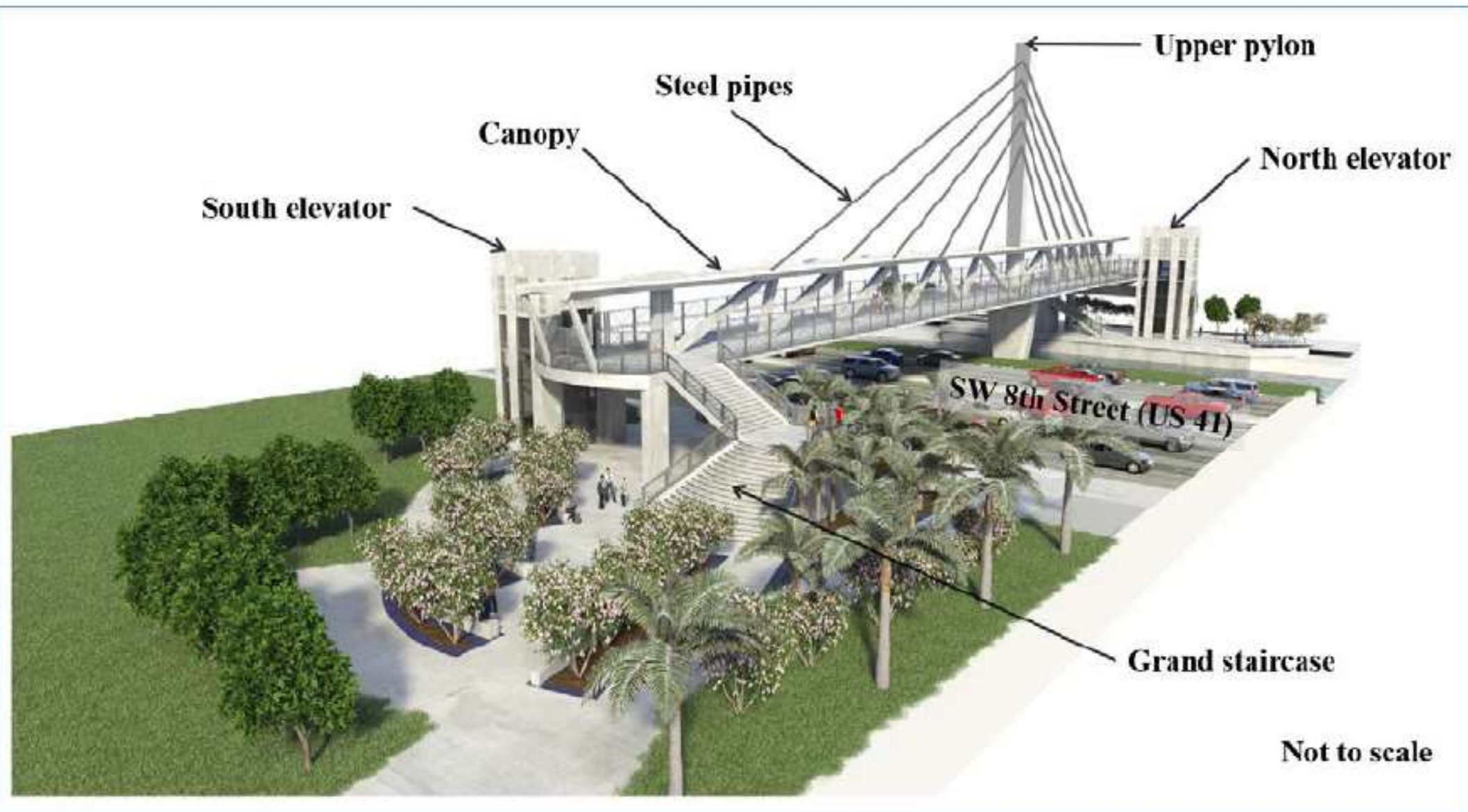
NTSB Response Operations Center







Miami, Florida. March 15, 2018

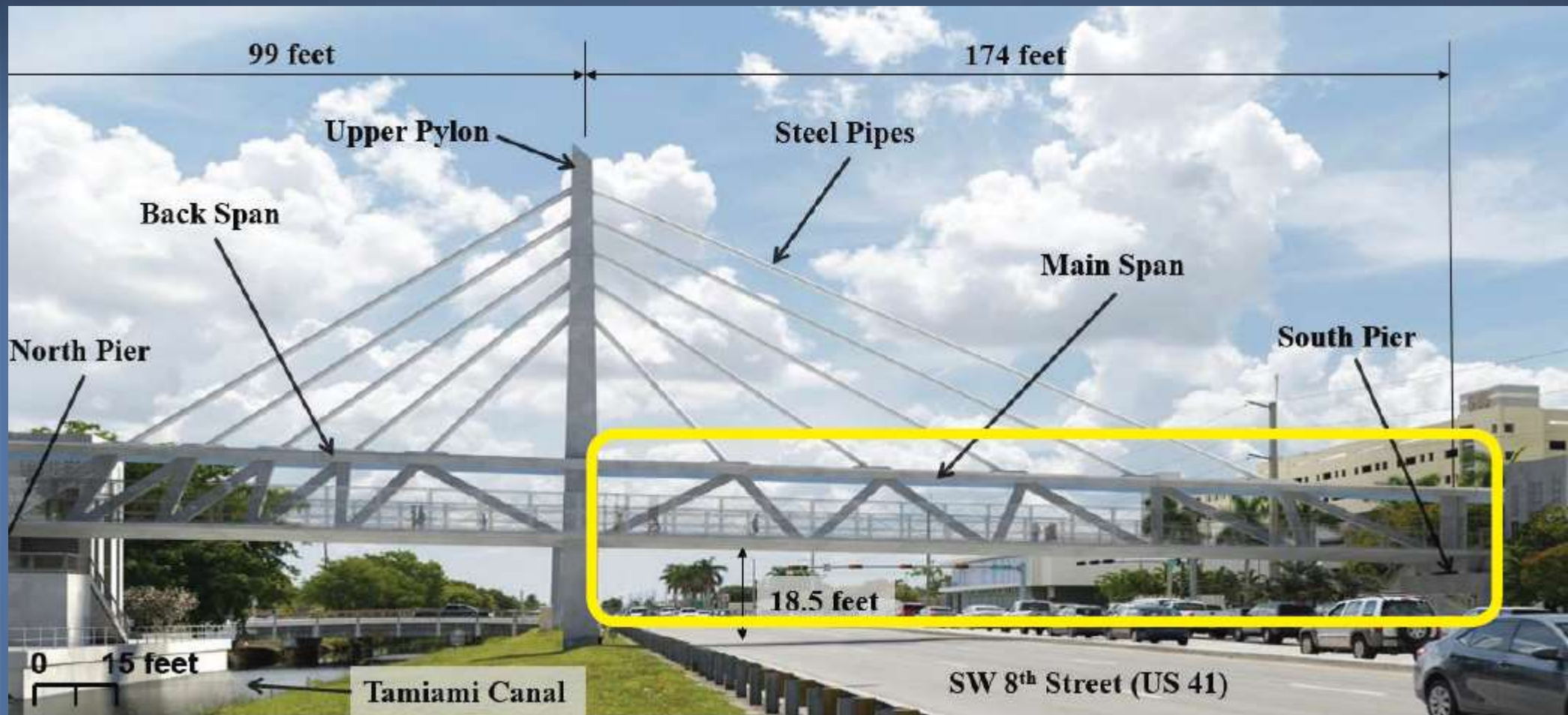




Walkway

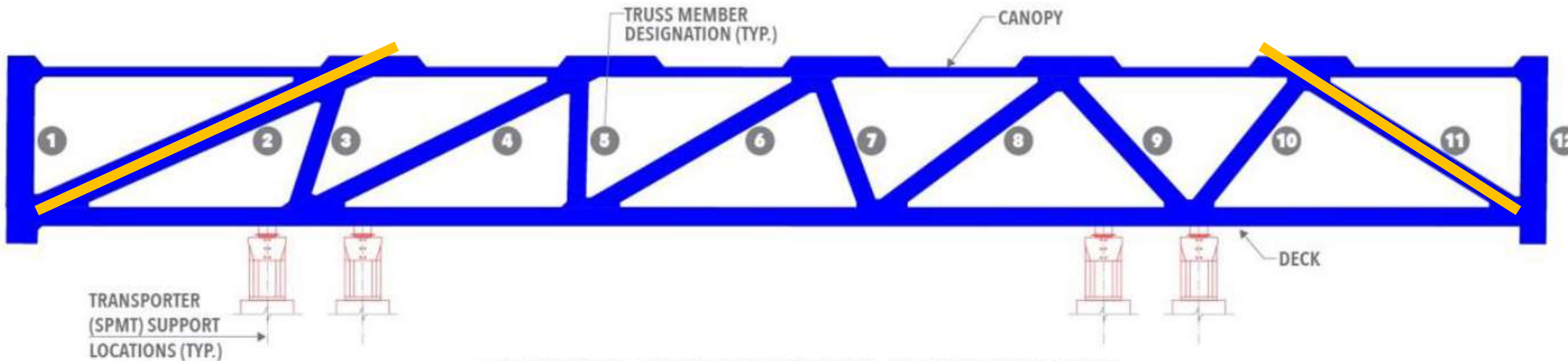
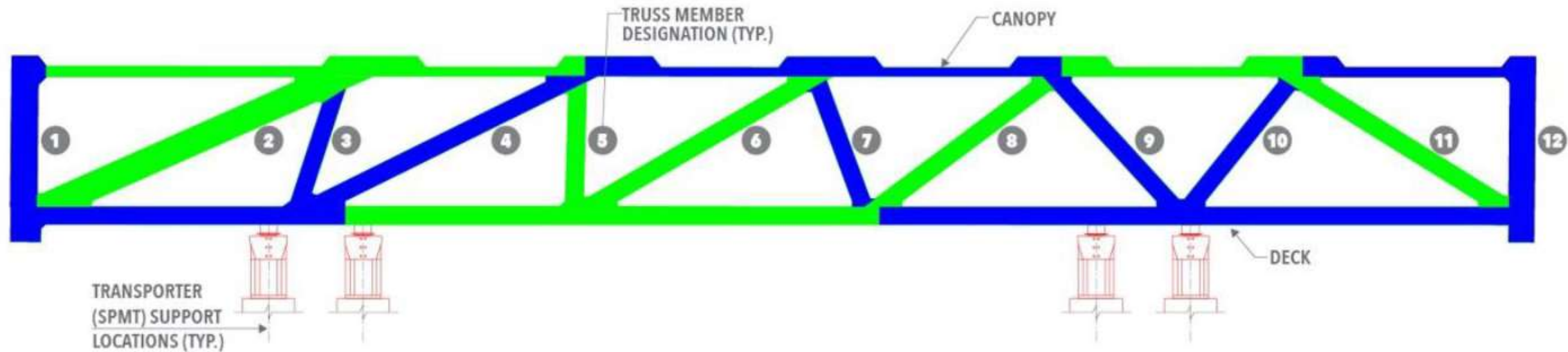


NTSB



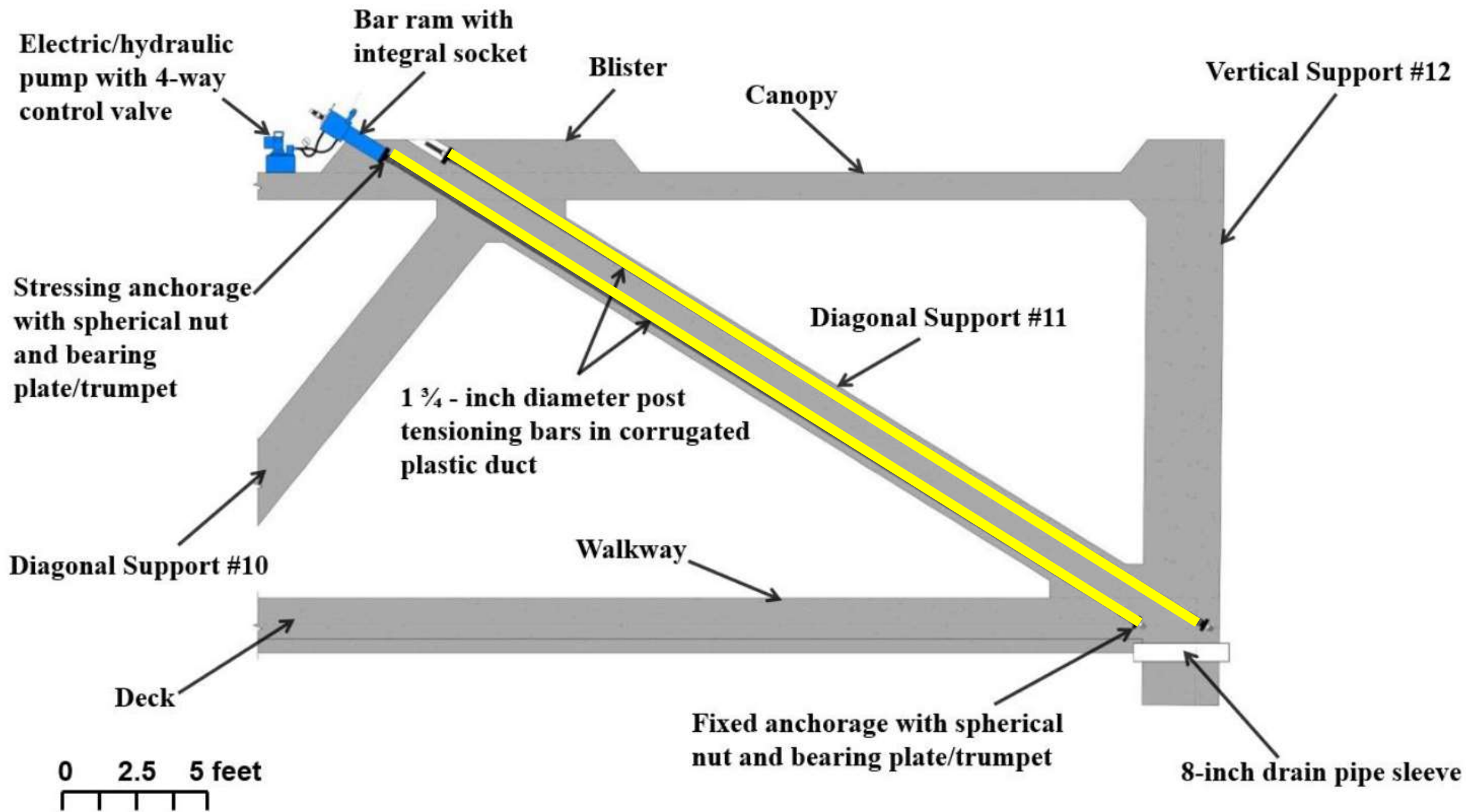
Accelerated Bridge Construction





SELF WEIGHT PLUS POST TENSIONING - MEMBER AXIAL LOAD

■ TENSION
 ■ COMPRESSION





March 10, 2018



March 15, 2018



Facing East

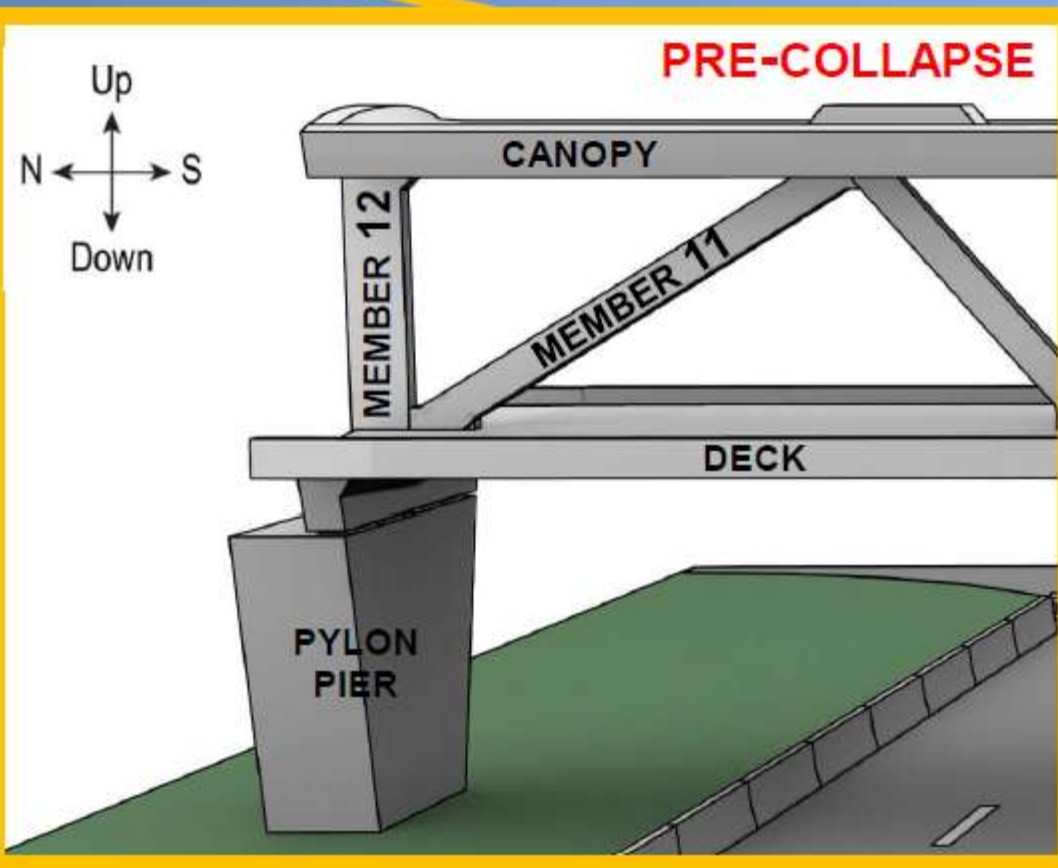
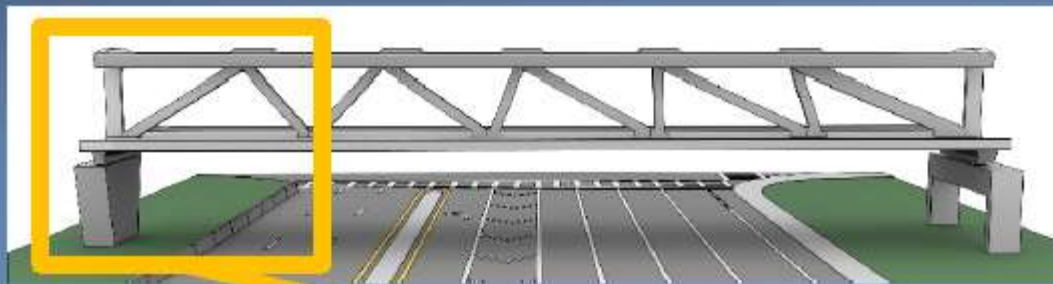


Concrete
blowout

12 11



SW 8th Street



Facing East

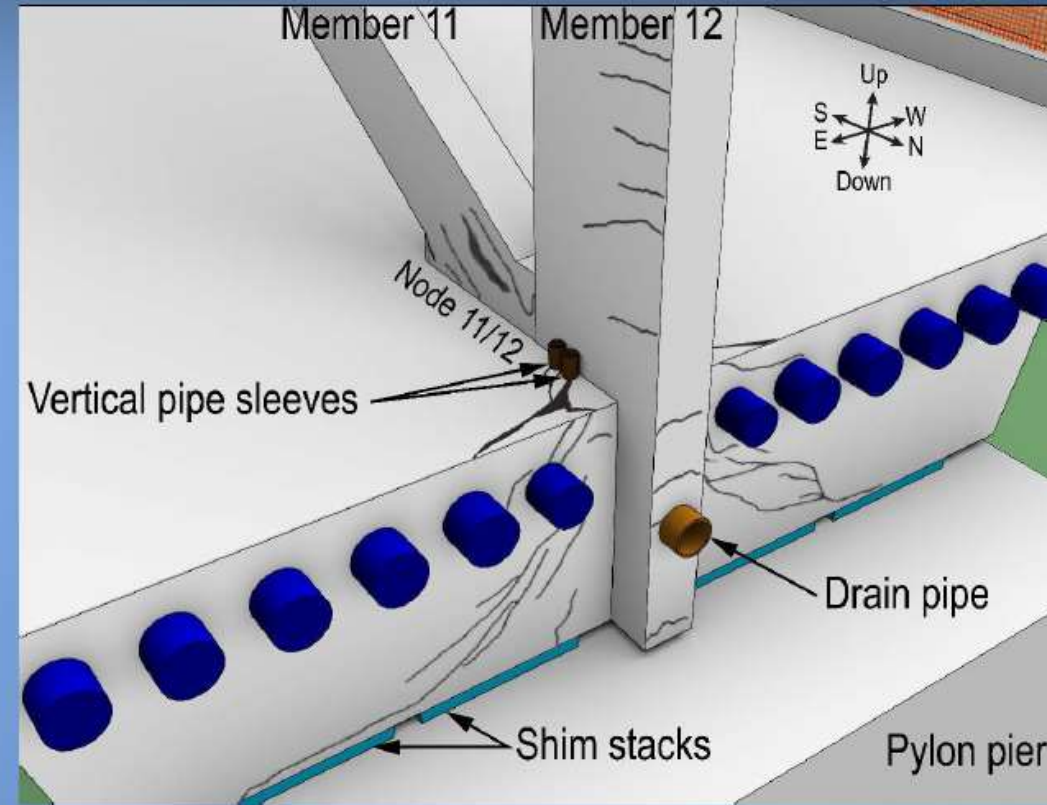


- **Concrete** - Tested compressive strength and tensile behavior.
- **Steel PT bars and rebar** – tested yield and tensile strength, and percent elongation.
 - Analyzed chemical composition of PT rods.

All material specimens were within specifications.

Cracking in Member 11/12 Nodal Region

- Structure showed notable cracking of reinforced concrete
- Extensive and large cracks in member 11/12 should have been recognized as abnormal
 - Cracks up to 0.016 inch wide – considered acceptable
 - Structural cracks in bridge were up to 0.75 inch wide – 40 times larger than typically acceptable
- Scale of cracking clear indication that load-resisting mechanisms were failing





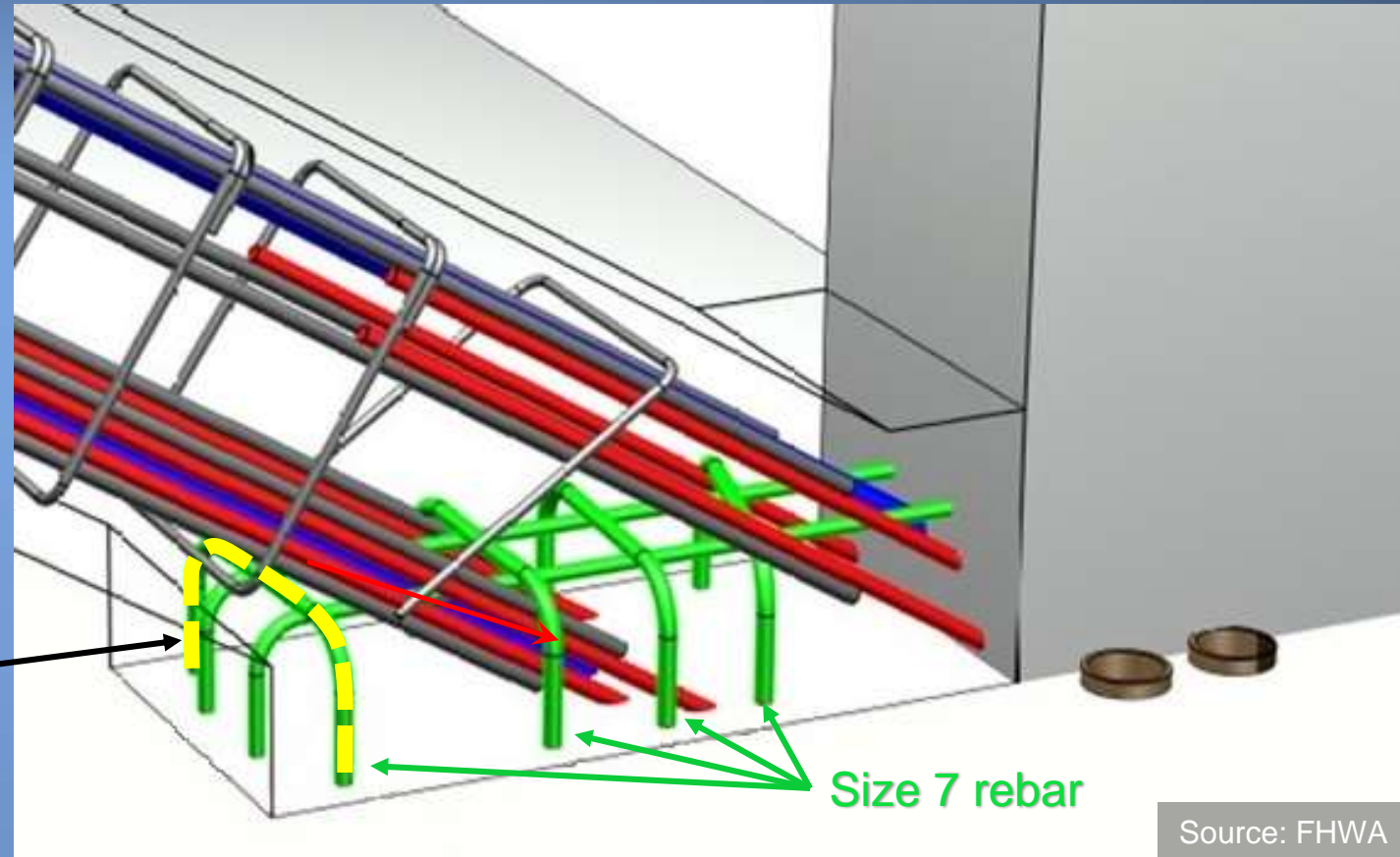


First Signs of Structural Distress

- Portion of crack bypassed 25% of reinforcing steel at base of member 11



Crack passed above the southernmost two size 7 rebars



Source: FHWA

Date	Time	Communication Method	Response
March 13	9:45 a.m.	Email from FIGG design manager to MCM	"We do not see this as a safety issue"
--	4:13 p.m.	Voice mail message from FIGG EOR to FDOT	"But from a safety perspective, we don't see that there's any issue there, so we're not concerned about it from that perspective"
--	5:18:22 p.m.	Email from FIGG design manager to MCM	"Again, we have evaluated this further and confirmed that this is not a safety issue"
March 14	10:50 a.m.	Email from MCM to Structural Technologies	"FIGG has further evaluated and confirmed that the cracks encountered on the diaphragm do not pose a safety issue and/or concern"
March 15	9:00 a.m.	Presentation by FIGG EOR at meeting with FDOT; FIU; MCM; Bolton, Perez (and others)	"And, therefore, there is no safety concern relative to the observed cracks and minor spalls"
--	--	Meeting minutes prepared by Bolton, Perez	"FIGG assured that there was no concern with safety of the span suspended over the road"
--	--	Meeting minutes of March 15 prepared by FIGG	"Based on the discussions at the meeting, no one expressed concern with safety of the span suspended over the road"

Conclusion

- Based on conservative calculations, it is concluded that the design meets LRFD strength requirements for this temporary condition ...
- And therefore there is no safety concern relative to the observed cracks and minor spalls

MIAMI
10:10 AM ET

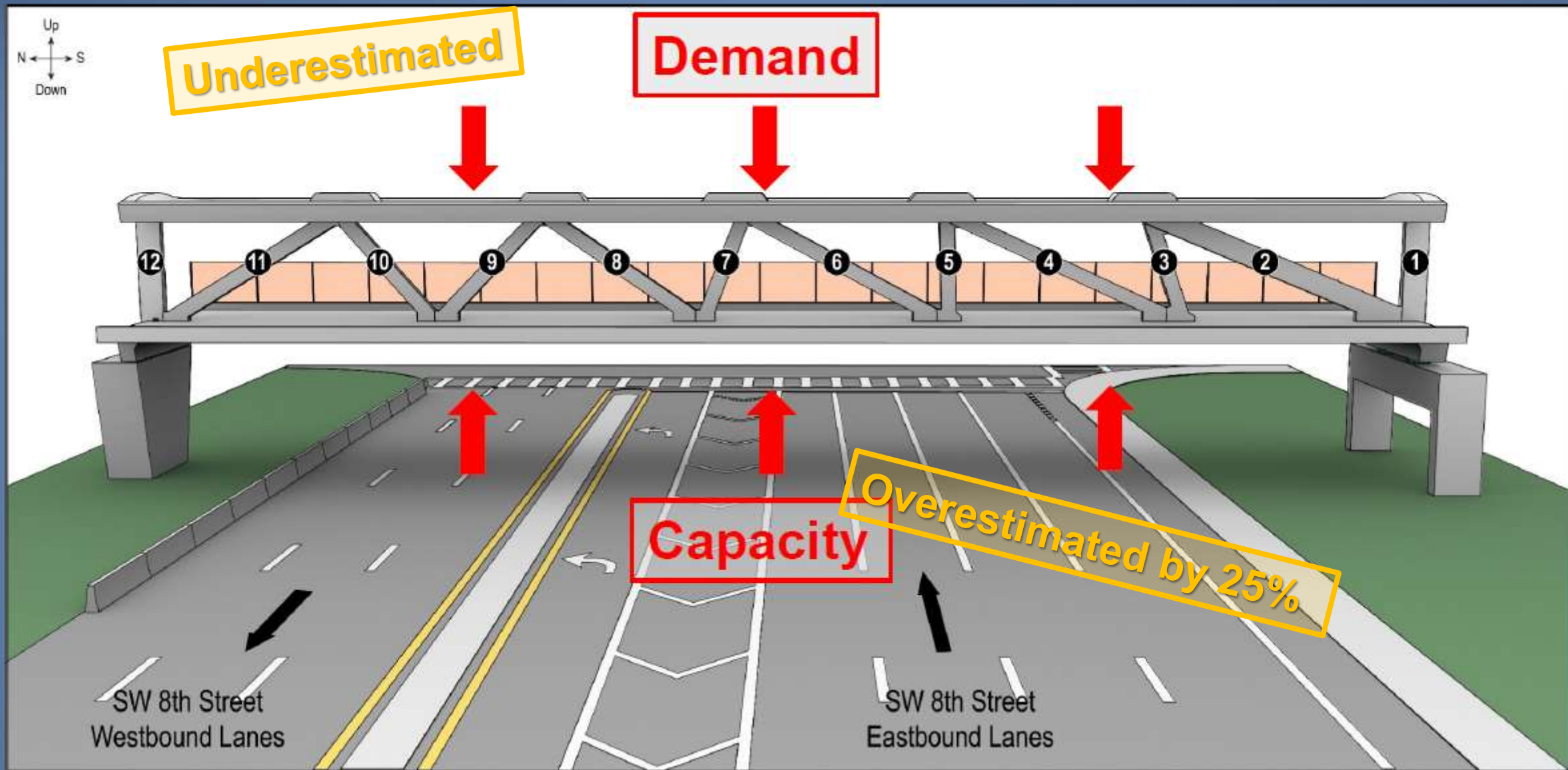


**NTSB CHAIR: NTSB HAS BROUGHT
A FULL INVESTIGATIVE TEAM**

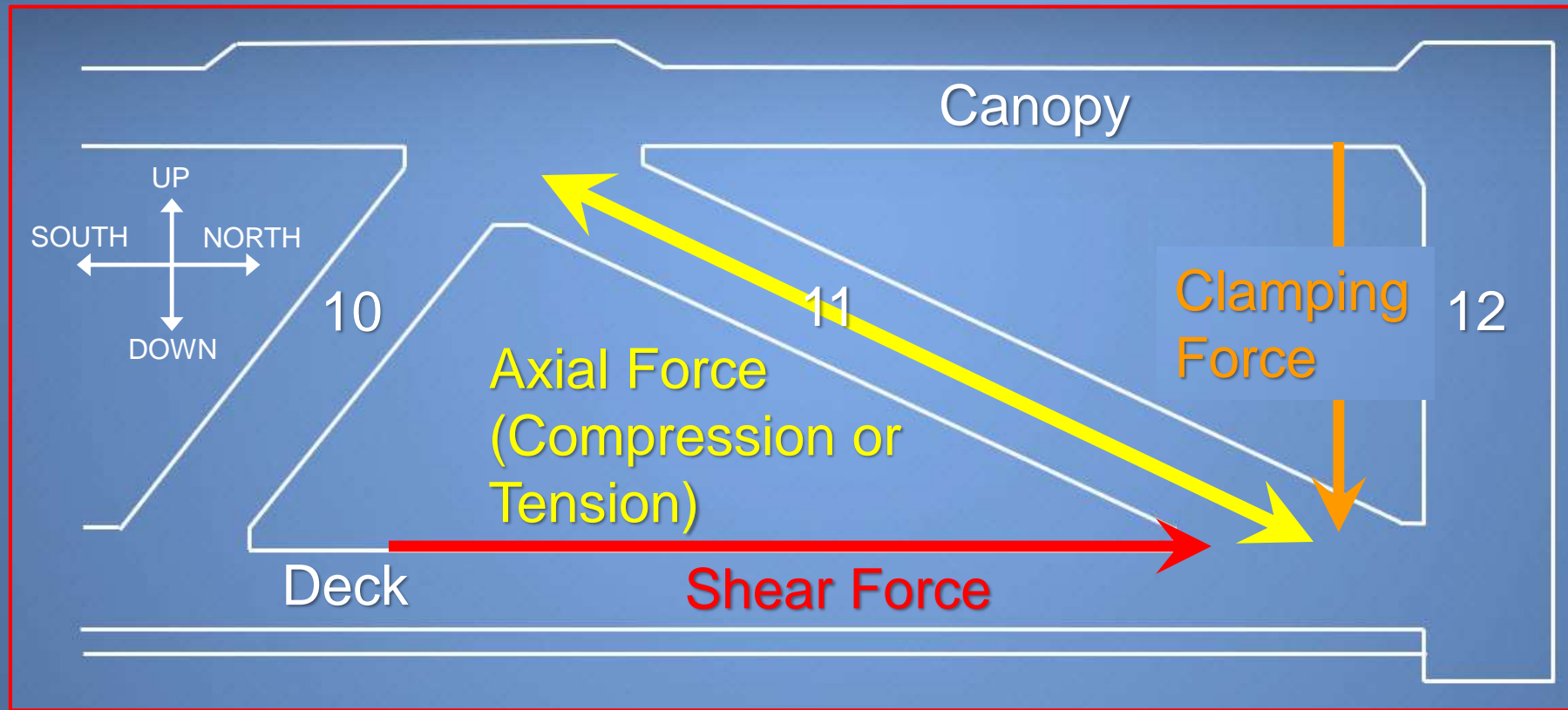
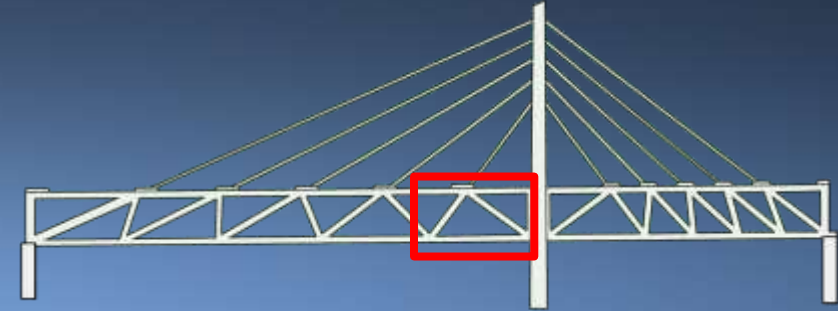
FOX NEWS ALERT

Critical Errors

- Bridge was under-designed
- Peer review was insufficient
- Failure to close bridge to traffic and workers

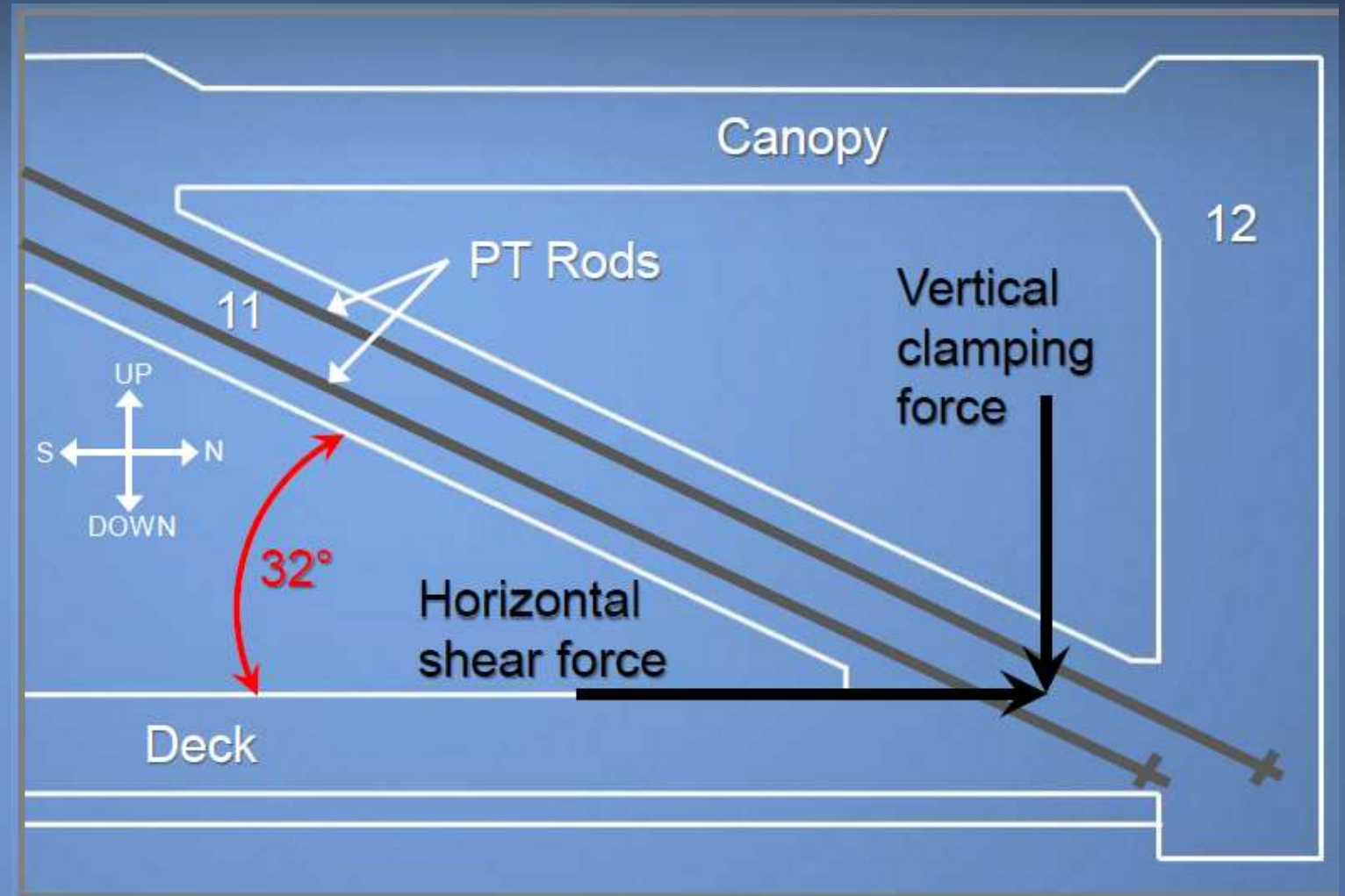


Forces on 11/12 nodal region



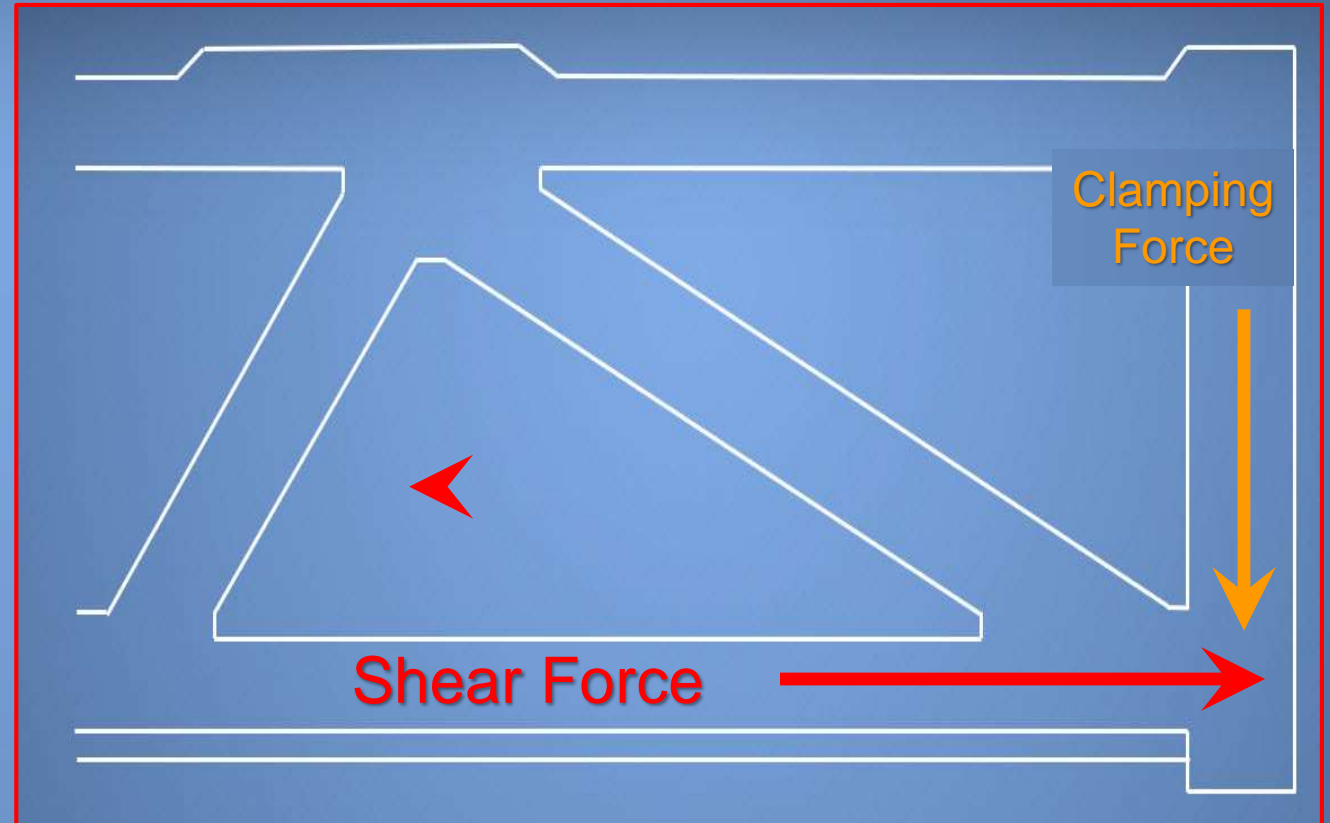
Magnitude of
horizontal force –
60 percent larger
than vertical force

Facing West

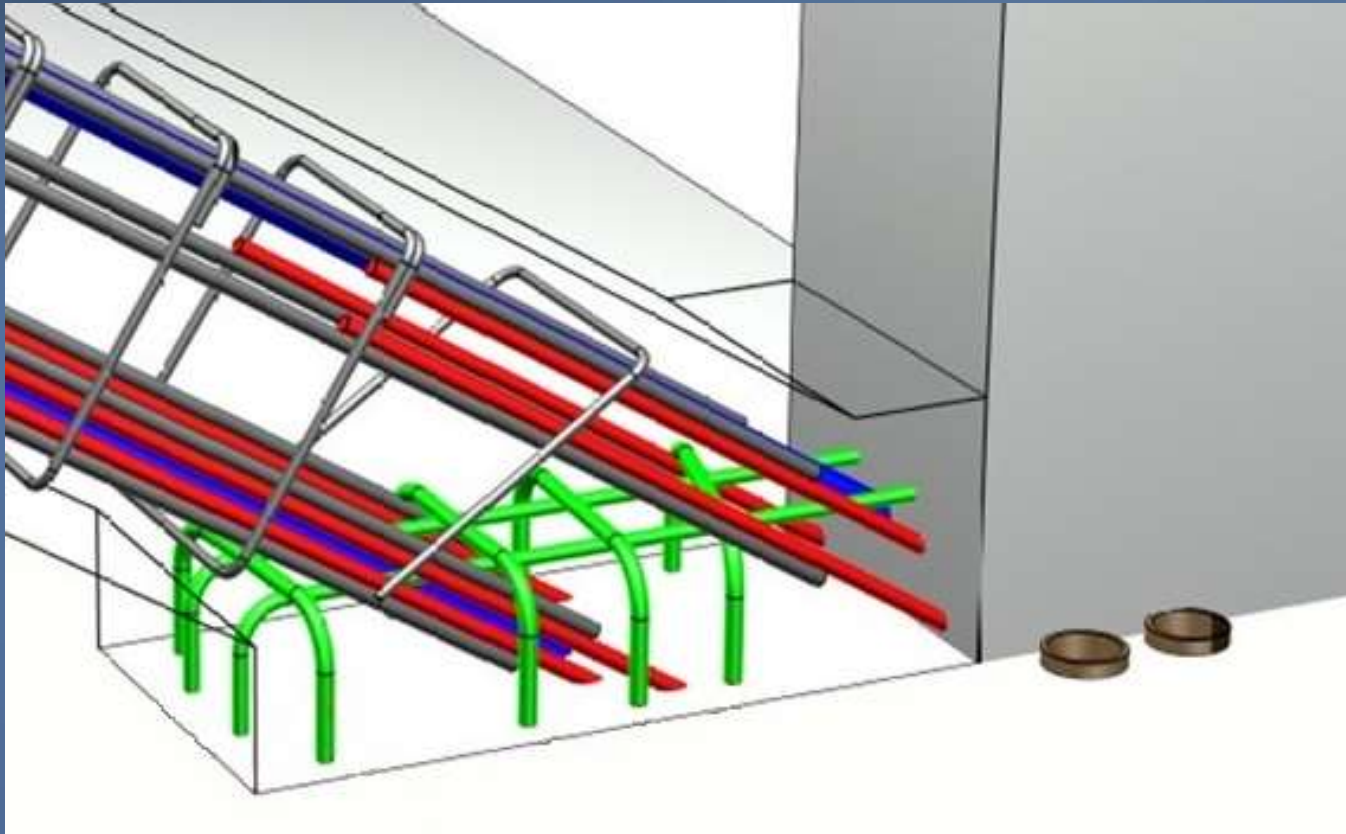


Interface Shear Demand

Figg underestimated interface shear demand at nodal region 11/12 by 46%.



270 percent more rebar needed



- Member 11 needed 18 square inches cross sectional area of rebar.
- It only had 4.8 square inches.

Summary

- FIGG design made significant errors in determination of loads
- Chose the wrong interface shear demand value
 - Led to a severe underestimation of demand
- Chose the wrong load factor in calculating the permanent compression loading, or P_c
 - Led to a significant overestimation of capacity

The National Transportation Safety Board (NTSB) determines that the probable cause of the Florida International University (FIU) pedestrian bridge collapse was the load and capacity calculation errors made by FIGG Bridge Engineers, Inc., (FIGG) in its design of the main span truss member 11/12 nodal region and connection to the bridge deck. Contributing to the collapse was the inadequate peer review performed by Louis Berger, which failed to detect the calculation errors in the bridge design. Further contributing to the collapse was the failure of the FIGG engineer of record to identify the significance of the structural cracking observed in this node before the collapse and to obtain an independent peer review of the remedial plan to address the cracking. Contributing to the severity of the collapse outcome was the failure of MCM; FIGG; Bolton, Perez and Associates Consulting Engineers; FIU; and the Florida Department of Transportation to cease bridge work when the structure cracking reached unacceptable levels and to take appropriate action to close SW 8th Street as necessary to protect public safety.



40
YEARS
in 2018

Exclusively
Specializing
in Bridges



CREATING BRIDGES AS ART®

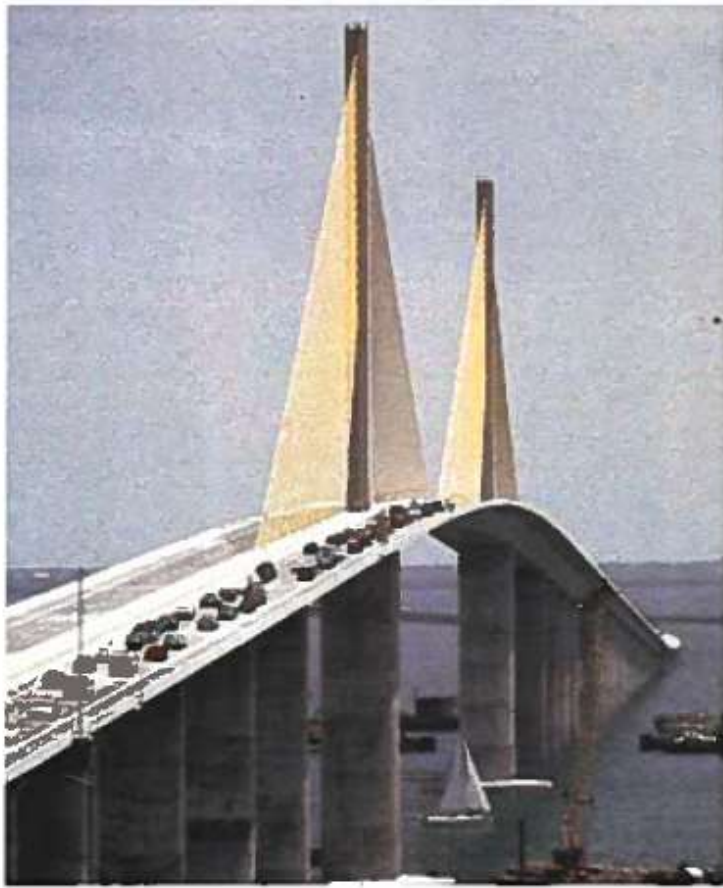


OVER 230 BRIDGES

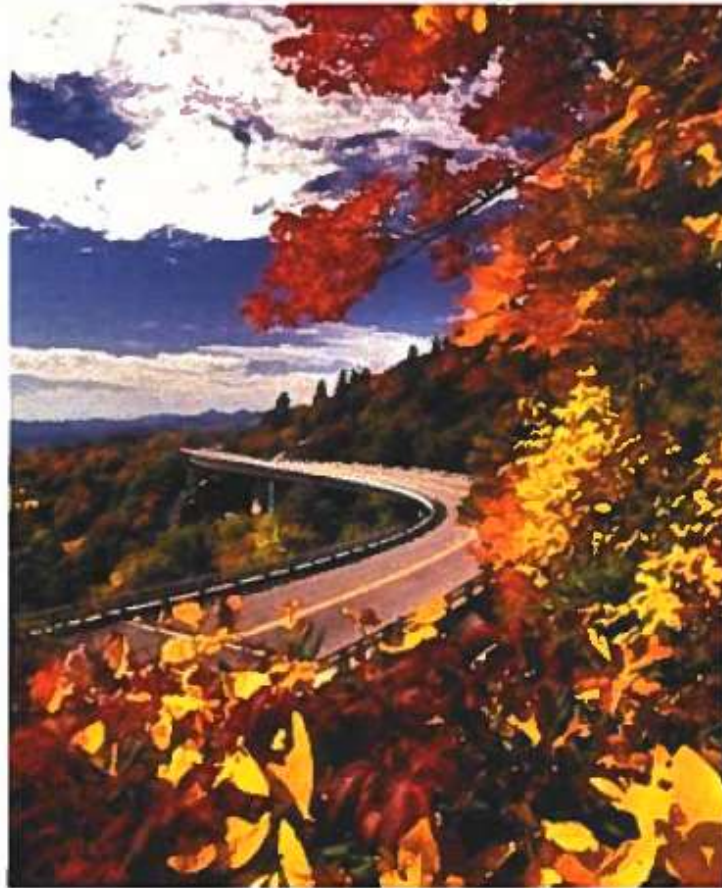
42 States
6 Nations

Brazil
Columbia
Guyana
Canada
India
Saudi Arabia





Sunshine Skyway Bridge, FL



Blue Ridge Parkway Viaduct, NC
National Park Service



Natchez Trace Parkway Arches, TN
National Park Service

3 Presidential Awards
through the National Endowment for the Arts
-US Presidents gave 5 of these awards for Bridges-



CREATING BRIDGES AS ART®

FIGG Has Delivered More Concrete Cable-Stayed Bridges than any Firm in America

14 built concrete cable-stays in U.S.

12 FIGG responsible charge

**7 Engineer of Record -
A first for each state**

**5 Precast concrete -
Engineer of Record For All of them**



BRIEF

TxDOT seeks removal of FIGG from \$800M Harbor Bridge design



Designer FIGG Removed From One Bridge Job, Faces Scrutiny on Second



FIGG Presentation on Day of Collapse

Conventional Method

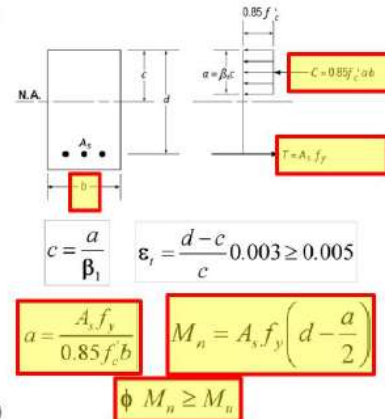
Rectangular Beam Analysis

Data:

- Section dimensions – b, h, d, (span)
- Steel area - A_s
- Material properties – f'_c , f_y

Required:

- Nominal Strength (of beam) Moment - M_n
- Required (by load) Design Moment - M_u
- Load capacity



Total Nodal Shear Stability

$$V_{ni} = cA_{cv} + \mu (A_{vf}f_y + P_c)$$

- $c \times A_{cv} = 57.6 \text{ k/sf} \times 23.62 \text{ sf}$
 - $\mu \times A_s F_y = 1.4 \times 22.72 \times 60$
 - $\mu \times P_c = 1.4 \times 520 \text{ kips}$
- $= 1360 \text{ kips}$

$= 1908 \text{ kips}$

$= 730 \text{ kips}$

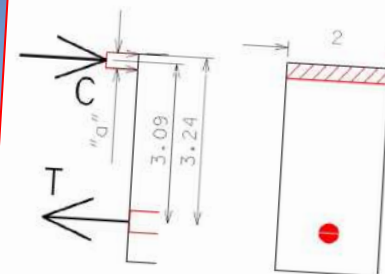
$= 3947 \text{ kips Total} = V_{ni}$
- FIGG's general preference is to neglect the Cohesion portion when practical. Thus, V_{ni} without "C" = 2638 kips
- ### Conclusions

 - The diagonal type ... with approved me...

Conclusions and Recommendations

- ## Conclusions and Recommendations
- The diagonal type cracks, in excess of FDOT criteria, should be sealed with approved methods and materials (Epoxy injection, etc.)
 - The spalled areas have not been replicated by the engineering analyses. However ...
 - The spalled areas are minor and it is recommended that they be prepared using normal procedures and poured back along with the upcoming "pylon diaphragm" pour (different from and prior to the falsework pours)

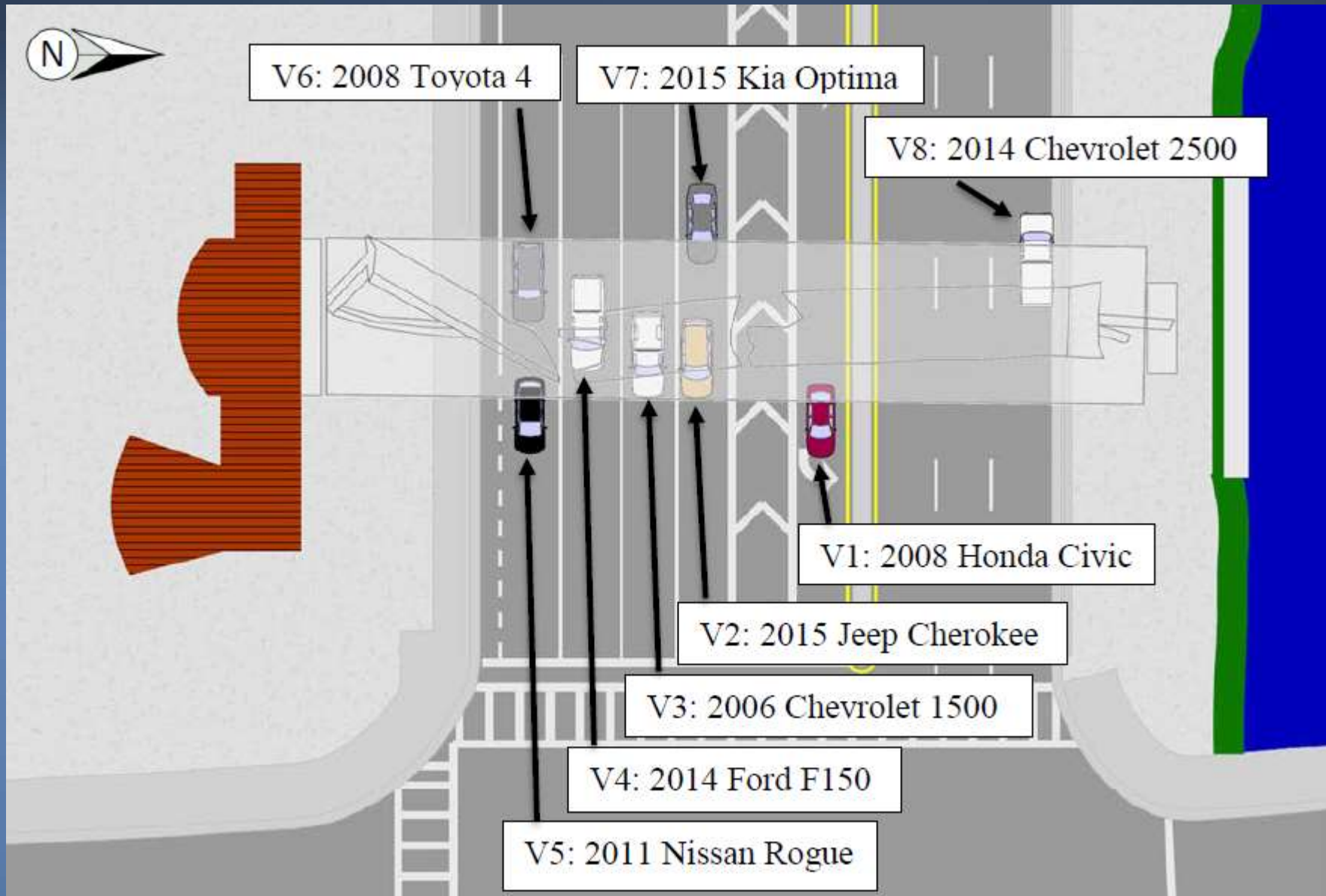
Bending Check – Beam Theory

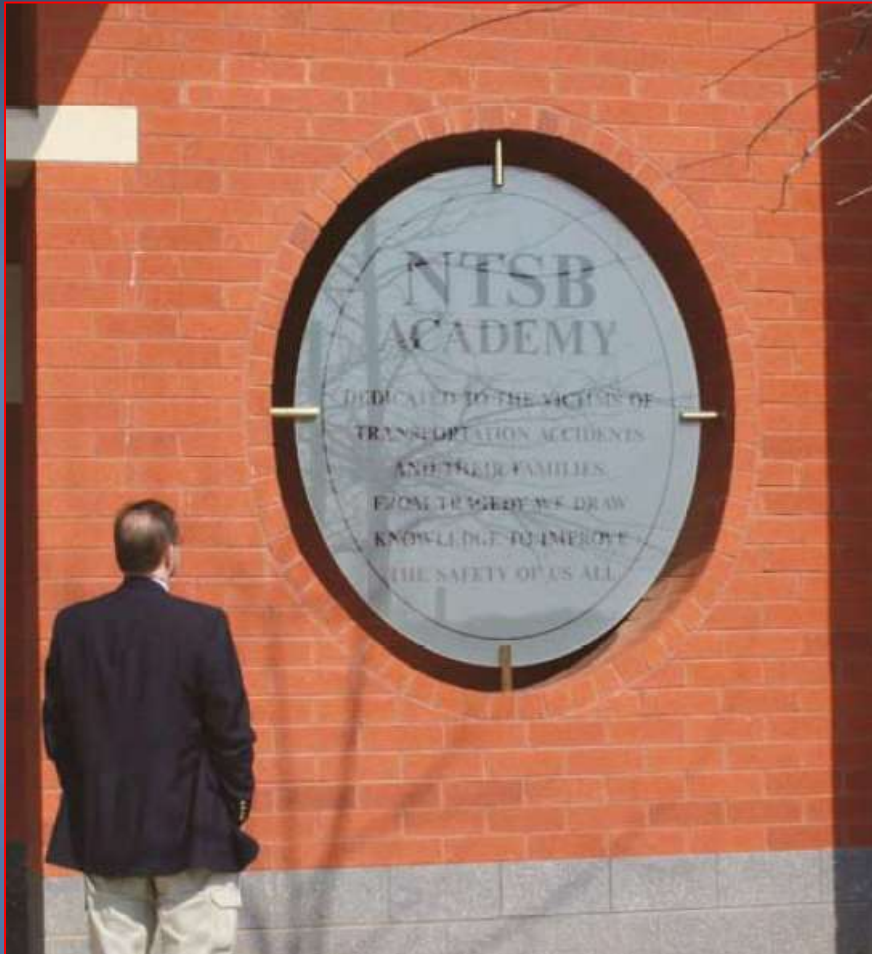


- Steel Area = 13.1 in^2
- $T = (13.1)(60 \text{ ksi}) = 786 \text{ kips}$
- $f'_c = 8.5 \text{ ksi} = 1224 \text{ ksf}$
- $(a)(.85 f'_c)(b) = C = 786 \text{ kips}$
- Solving, "a" = 0.38 ft
- $M_n = (T)(d - (a/2)) = 786 \times 3.09' = 2398 \text{ kip-ft (nominal capacity)}$
- $\Phi = 0.9$, so $(\Phi)(M_n) = 2158 \text{ kip-ft}$
- Which is larger than $M_u = 2015 \text{ kip-ft}$
- Check OK

Conclusion

- Based on conservative calculations, it is concluded that the design meets LRFD strength requirements for this temporary condition ...
- And therefore there is no safety concern relative to the observed cracks and minor spalls





“From tragedy we draw knowledge to improve the safety of us all.”



National Transportation Safety Board